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## PRACTICE IN THE CASE OF ADDITION.

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The experiment reported here was designed to secure information concerning only the amount and rate of improvement and the value of the practice experiment as a method for school work. The practice was not continued long enough nor taken under uniform enough conditions to justify inferences concerning changes in the rate of improvement; and I shall make no attempt to analyze out the factors producing the improvement.

The experiment consisted in adding daily for seven days forty-eight columns each of ten numbers (no 1's or 0's being included). Seven printed blanks had been arranged of equal difficulty.<sup>1</sup> The forty-eight sums were written. The time required was recorded in seconds. The subjects were nineteen university students—eight men and eleven women.

The time taken and the number of examples wrong for each set for each of the nineteen subjects are recorded in Table I. Table II repeats Table I with an addition of one per cent. of the time for forty-eight examples for each example wrong. That is, I estimate that half the time for one example is a just allowance to balance its inaccuracy. This system of allowance is, of course, arbitrary, but it will not prejudice any of the conclusions which I shall draw. They would be the same by any reasonable allowance. Table III summarizes conveniently the facts as to the amount and rate of improvement, and its relation to initial ability.

Taking the whole group together, improvement in speed and in accuracy are about equal, the median reduction in time regardless of errors being 31 per cent. and the median reduction in errors regardless of time being 29 per cent. By the scores with allowance for errors the median improvement in general efficiency in addition is 33 per cent. The average improvement is 29 per cent. This is for less than one hour of practice (about fifty-three-minutes).

The individuals vary from cases making no improvement (F and G) to a case of nearly fifty per cent. improvement (K).

That the practice represented by only 2,592 additions made by an educated adult whose addition associations have been long established and often used should produce an improvement of three-tenths, bears witness to the continued plasticity or educability of the synapses involved. It also supports the contention that the degree of efficiency shown by persons in any intellectual function is a result chiefly of specific training in it or the elements of it and only slightly of the transfer to it of the effects of training other functions. If the general training of from fifteen to twenty-five years of a scholarly life were responsible for a large fraction of one's efficiency in "quickness of association" or "accuracy in response," one would not by so little specific training be able to improve so much.

The amount of improvement in this experiment may also add to our confidence that the method of the practice experiment wherein

<sup>1</sup> The improvement is measured from the average of series 1 to the average of series 7, that is, over 6 X 48 examples, each involving nine additions.

one works at one's limit and competes with one's own past record may well be made a regular feature in many school drills. Even if the same length of time produced in children a percentile improvement only half as great as here, the gain would still probably be far greater than the gain by any of the customary forms of drill.

TABLE I  
*Gives Scores in the Seven Successive Practice Periods*

Individual	Sex	Day of beginning	Intervals between tests	Hours	First	Second	Third	Fourth	Fifth	Sixth	Seventh								
					Time	Examples wrong	Time	Examples wrong	Time	Examples wrong	Time	Examples wrong							
A	m	M	24		550	3	530	5	420	3	420	4	430	4	402	2	382	4	382
B	m	T	24		620	2	420	4	325	6	420	7	360	9	360	13	345	5	345
C	m			not reported	560	4	570	3	545	4	515	4	480	1	455	4	470	2	470
D	m	W	24	except 48 between 4-5	482	18	470	11	420	6	360	9	420	8	300	9	302	8	302
E	m	W	24	except 48 between 4-5	1020	3	810	2	770	4	680	5	735	6	650	7	605	1	605
F	m	W	24	except 48 between 4-5	800	3	710	2	715	2	700	3	695	1	655	4	785	3	785
G	m			not reported	600	0	560	0	510	0	465	0	465	4	468	4	455	0	455
H	m	T	24	except 72 between 4-5	456	5	390	4	325	3	329	3	368	7	320	3	310	2	310
I	f	W	24	except 72 between 3-4	420	2	360	0	450	0	450	1	450	1	480	4	470	4	470
J	f	W	24	except 48 between 4-5	641	3	630	5	608	3	640	5	550	1	545	1	475	0	475
K	f	W	24	except 48 between 4-5	460	0	375	1	362	0	307	0	297	3	243	2	240	1	240
L	f	T	24	except 48 between 4-5	560	8	520	3	540	3	440	3	500	0	390	3	385	5	385
M	f	T	24	except 48 between 5-6	590	4	420	3	360	0	350	1	345	0	330	0	360	0	360
N	f	T	24	except 48 between 5-6	750	8	740	2	605	1	600	3	650	5	550	4	500	6	500
O	f	W	24	except 48 between 2-3	420	5	680	1	470	1	495	0	435	3	434	3	410	0	410
P	f			not reported	870	14	840	11	795	13	630	16	610	7	600	5	530	10	530
Q	f	W	24	except 48 between 4-5	840	4	750	1	690	1	675	0	700	1	645	0	630	0	630
R	f	W	24	except 48 between 4-5	690	2	625	3	580	1	510	3	560	3	555	3	470	3	470
S	f			not reported	866	2	680	1	725	1	595	3	590	1	580	2	520	2	520

TABLE II

*Scores Reduced to Single Variables by Allowance for Examples wrong*

Individuals	Sex	First	Second	Third	Fourth	Fifth	Sixth	Seventh
A	m	565	555	432	436	446	410	398
B	m	632	436	345	448	390	405	362
C	m	582	587	567	536	485	473	479
D	m	570	520	445	392	454	327	326
E	m	1050	834	800	714	780	695	611
F	m	824	724	729	721	702	681	808
G	m	600	560	510	465	483	486	455
H	m	479	406	335	339	393	330	316
I	f	428	360	450	455	455	499	489
J	f	660	662	626	672	555	550	475
K	f	460	379	362	307	306	248	240
L	f	606	535	556	453	500	402	404
M	f	614	432	360	354	345	330	360
N	f	810	755	611	618	670	572	530
O	f	441	687	475	495	448	447	410
P	f	992	932	897	730	653	630	583
Q	f	874	758	697	675	707	645	630
R	f	707	644	586	525	577	571	484
S	f	883	687	732	613	596	592	530

The relation of the amount of improvement to initial ability in any practice experiment is of great interest because it gives evidence bearing upon the fundamental problem of the relative shares of original nature and environment in determining the achievements of men.

It has been shown that in the case of educated adults the relative (that is, percentile) differences amongst educated adults in the ability to multiply mentally a three-place number by a three-place number are left unreduced by submitting all the individuals to equal practice.

The differences amongst individuals in the ability to add seem to be due in larger measure to differences in environmental influence. For equal practice does here reduce a little the relative or percentile differences within our group. This will be seen by comparing the relative variability of the group in the seventh practice period with that in the first, or by calculating the co-efficient of correlation between initial ability and percentile improvement. The proportions for highest and lowest individuals, next to highest and next to lowest are:

	1st 19th	2nd 18th	3rd 17th	4th 16th	5th 15th
In first practice period	2.45	2.25	1.92	1.82	1.46
In second practice period	3.36	1.99	1.87	1.62	1.46

The correlation between initial ability and percentile improvement is negative, roughly— $\frac{1}{4}$ .

There is, of course, no essential conflict between this result for addition and the opposite result for mental multiplication with two

three-place numbers. The same theoretical view which would expect mental span and ability to manage very complex relationships in a given field to be increased by practice in close dependence upon original capacity, would expect particular associative habits such as thinking of thirteen upon seeing 4, 7 and 2 in a column, to be increased by practice in less close dependence upon original capacity.

TABLE III  
*The Amount of Improvement in Relation to Initial Ability*

Individual	Sex	Initial Ability	Gross Improvement	Percentile Improvement
A	m	565	167	.30
B	m	632	270	.43
C	m	582	103	.18
D	m	570	244	.43
E	m	1050	439	.42
F	m	824	16	.02
G	m	600	145	.24
H	m	479	163	.34
I	f	428	61 (loss)	.14 (loss)
J	f	660	185	.28
K	f	460	220	.48
L	f	606	202	.33
M	f	614	254	.41
N	f	810	280	.35
O	f	441	31	.07
P	f	992	409	.41
Q	f	874	244	.28
R	f	707	223	.31
S	f	883	353	.40
Medians,		614		33
Averages,		674		29

The improvements recorded are of the seventh set of 48 ten-figure examples over the first such set. They represent approximately the practice effect of 2,192 additions, or of from 30 to 75 minutes work.